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Periodontal Ligament Reaction Associated with Two Methods of Dowel Space Preparation

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PERIODONTAL LIGAMENT REACTION
ASSOCIATED WITH TWO METHODS
OF DOWEL SPACE PREPARATION

by

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VITA

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The author has published the following works:

1. Cratty, B.J., Trabert, K.C., and Hanson, E.C.: The psychomotor skills of dental trainees, Monograph from UCLA School of Dentistry, Summer Trainee Enrichment Program, 1972.

2. Hanson, E.C., Caputo, A.A., and Trabert, K.C.: The optimum relationship between pins, cements, and retention, J. Prosthet. Dent. 32:428-434, 1974.

3. Hanson, E.C., and Caputo, A.A.: Cementing mediums and retentive characteristics of dowels, J. Prosthet. Dent. 32:551-557, 1974.

4. Trabert, K.C., Caputo, A.A., and Hanson, E.C.: Effects of cement type and thickness upon retention of serrated pins, J. Dent. Res. 54:227-231, 1975.

5. Hanson, E.C., Caputo, A.A., and Trabert, K.C.: Readers' roundtable contribution, J. Prosthet. Dent. 34:226-227, 1975.

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CHAPTER I

INTRODUCTION

Only a few generations ago endodontic treatment was viewed as a dubious method of therapy by many dentists and most physicians. However, we have now entered into the golden age of endodontics, which is characterized not only by virtually complete acceptance by dental practitioners but also by the demand of dental patients to retain their teeth.

There have been many reasons for the constant ascendance of endodontics. The biologic basis of treatment has been deeply investigated and the efficacy of methods of therapy have been verified.[1-3] The adoption of instrument standardization as established by the Second International Conference on Endodontics has led to simplification and yet increase in sophistication in the clinical management of endodontics. Investigations on canal number and configuration have provided important information so that by being aware of what is actually present, chances for success are increased.[4-6]

While many teeth which formerly were extracted are now retained, the restorative dentist is faced with greater challenges and problems since these increased numbers of treated teeth may then serve singly and as abutments for fixed or removable prosthodontic appliances.

Endodontics saves the root; a restoration returns the tooth as a member of the total masticatory apparatus.[7] Endodontically treated teeth are deficient in sound coronal tooth structure due to caries, previous restorations, and endodontic access preparations. Frequently, only the remaining root in a healthy periodontal supporting tissue is available for restoration to function and aesthetics. In addition, it has been shown that the calcified material of pulpless teeth has less moisture content than that of vital teeth thereby making fracture more imminent.[8]

The proper restoration of the pulpless tooth is not any less important than the properly executed initial access opening into the canal. The most suitable restorations to encompass the remaining tooth structure are retained extra-coronally with a dowel which fits into the prepared root canal. The weakened tooth is thus reinforced and retained with a dowel and coronal core.[9]

Methods and materials utilized for the dowel and core fabrication vary. Techniques used in providing space for the reception of a dowel involve removal of axial dentin in the root canal. Basically, there are two methods of providing space for a dowel in a treated root. A frequently used procedure makes use of engine-driven rotary instruments while another utilizes hand instruments. The rotary instruments may be part of a kit used preparatory to placement of a proprietary dowel or for preparation of a canal for custom dowel fabrication.

Round or fissure burs have been used for enlarging the canal, but in unrestricted use they can easily produce a lateral perforation of canal walls.[10,11] Instead, graded Peeso reamers in sequential order may be used in a low speed contra-angle for removal of gutta-percha and increasing canal width.[12,13] The other technique involves softening of gutta-percha with a red hot plugger so that gutta-percha will adhere and can be withdrawn from the canal.[14] This procedure is repeated until the desired depth of penetration is obtained. Then, sequential use of hand reamers employing reaming action will enlarge the canal. One questions whether or not either of these techniques possess the potential to inflict change upon the supporting tissues of a tooth.

It was the purpose of this study to determine the histologic reaction of two methods of dowel space preparation upon the tooth, periodontal ligament and supporting alveolar bone in dogs. Do the rotational torqueing forces cause inflammation and/or retrogressive changes in the periodontal ligament? Does the placement of a heated instrument cause burn damage in these critical sites?

CHAPTER II

REVIEW OF THE LITERATURE

A. History of Dowels

The most ancient dental prosthetic appliances have been of the fixed bridge variety. From all reports these were constructed by the Phoenicians and not the Egyptians.[15] Brown states that modern Egyptologists know of no specimen of ancient Egyptian prosthetic dentistry.[16] The early prosthodontists attempted not only to replace missing teeth but to stabilize weak teeth to adjacent teeth.

Up to the time of Pierre Fouchard, the father of modern dental prosthesis, dentistry consisted of ligating in tooth replacements (single and multiple) and covering teeth with plates of gold but essentially no particular technical advances were made.[15] Practicing in Paris, Fouchard used what he called "tenons" which were dowels screwed into roots to retain some of his bridges. In fact, he may have been the first to attach dental bridges to tooth roots by this method.

Until as late as 1850, restorative dentistry was still in a state of crude development. After this, progress was then well on its way from the foundations laid down by the French during the latter part of the 18th century.

The most popular method during the middle 19th century for restoring lost coronal surfaces was by the placement of a "pivot" crown. A wooden pivot was adapted to a crown and to the canal of a remaining root. The assembly was put into place and held there until the moisture of the oral cavity caused the wood to swell, thus affording sufficient anchorage. However, this could possibly cause the root to split.

The dental practitioners of this period were unaware of the periapical pathosis initiated when abutment teeth were devitalized for the purpose of establishing greater mechanical retention by means of placing dowels into the root canals. It was common practice to cut off the crown of a healthy, sound tooth and place a porcelain-faced dowel crown to serve as a retainer for a bridge. Therefore, up to the early 20th century dentists were working purely on mechanical grounds producing complicated crowns and bridges that were adapted to hopelessly diseased and broken-down roots. As a result William Hunter condemmed dentists who constructed "gold traps of oral sepsis."[17]

For a few years following Hunter's denouncements, fixed bridgework was held in ill repute. It was Karl Knoche in 1918 and Forrest Orton in 1919 who helped in the reformation of bridgework during that period. From that time on, studies in technical perfection and great attention to mechanical detail evoked a revitalization and trust in restorative dentistry. To this day, however, the complete intermarriage between mechanical application and biologic principles has been slow to occur although much progress has been made.

When discussing dowels, the dowel crown must be mentioned. This involves the incorporation of dowel and crown as an integral unit. The coronal portion may be composed of gold, acrylic, porcelain, or combinations thereof. This type of crown gains retention and resistance to displacement primarily from the dowel that extends into the root canal and the grasping of the available root face.

Integral dowel and crown restorations are historically some of the oldest forms of restorations for endodontically treated teeth. As an example, the Richmond crown includes the single-unit replacement of dowel and clinical crown. The Davis crown is similar but uses a root facer to prepare the root stump to coincide with the manufactured porcelain teeth and dowels.[12] Common weaknesses observed in these crowns have been fracture of the root, fracture of the dowel, fracture of the facing as well as inadequate marginal fit. In addition, Frank recommends that if the slightest possibility exists that this tooth in the future will serve as a bridge abutment or remake of casting done, the dowel crown should be avoided.[18]

The two-segment restorative procedure where the dowel and core is cemented prior to cementation of the separate extracoronal retainer is highly recommended by some investigators.[13,19,20] There are distinct benefits afforded to both patient and dentist. For example, the final restoration can be remade to change tooth form or color, the crown can be more easily changed into a retainer for a bridge, and the core can be easily constructed and developed parallel with the other abutment(s).[21] In addition, retention and stability of the dowel and the crown can be ascertained separately and more precisely and replacements and repairs can be done without disturbing the cemented dowel and core substructure. The clinical procedure is less complicated in that greater accuracy of marginal fit can be obtained in adapting the final extracoronal casting since the dowel and core have been previously adapted and cemented. Types of two-segment restorations include a finished crown covering a substructure of cast dowel and core, proprietary dowel and core, or a pin-reinforced core.

These types of restorations tend to distribute those concentrated forces which could fracture the crown from the root. Being firmly attached to and encased by a solid bony housing, the root resists the forces applied to the crown. Investigations have shown that the greatest shear is at or near the height of periodontal attachment.[12,21,22] This imaginary line extends around the periphery of each pulpless tooth. The dowel reinforcement portion of the restoration blends internal strength from root to crown thereby retaining crown-to-root integrity and continuity.[12]

B. <u>Dowel Parameters</u>

Dowels can be separated into basic groups according to their geometrical configuration: tapered, parallel, and threaded. Retention may be gained by the utilization of dentinal resiliency or by cement alone. Dowels are available in gold, high-fusing precious metal alloys, aluminum, or plastic depending on the particular technique selected. They may be custom made or prefabricated.

Custom dowel fabrication by the direct technique has been advocated by Dewhirst, and co-workers.[13] Here, cast gold dowels are made from reinforced direct acrylic resin patterns. Graded Peeso reamers are generally used to remove the gutta-percha and to enlarge the canal. This type of engine reamer with its blunt non-cutting tip, will follow the path of least resistance, i.e., the gutta-percha in the canal. Gerstein and Burnell suggested the use of prefabricated, high-fusing, precious metal precision dowels which are stronger than cast dowels of the same chemical composition.[23] Here the dowels have a diameter and taper equal to the diameter and taper of new standardized files and reamers as approved by the research council of the American Association of

Endodontists. The sizes range from #70 to #110. Weine, *et al.*, developed a plastic pin for use in prepared root canals as an aid in constructing cast dowels and cores.[24] These pins are available in standardized sizes of #80 to #140 with the standardized color-coding for identification purposes. A proprietary precious metal precision dowel, the Endo-Post,* is available for insertion into canals prepared by standardized files or reamers in sizes #70 through #140. Resin or wax cores can be built up. These dowels are available for regular and high-fusing metal casting techniques.

Kurer has offered another solution to the problem of reinforcing endodontically treated teeth.[25] His system employs engine-driven root reamers whereby the canal is prepared to the proper length and then tapped such that the dowel may be screwed in and cemented. The dowel is of a parallel threaded design available in sizes corresponding to the provided root reamers. A brass core is an integral part of the dowel which can be prepared for the reception of an extracoronal retainer. With this system Standlee, *et al.*, warn that the operator should be aware that tapping procedures may initiate dentinal damage unless done slowly and carefully.[26] It was also shown that in function these dowel and cores

*Kerr Manufacturing Co., Romulus, MI

localize stress around the threads and coronal interface.

The Para-post* system consists of a cemented, serrated parallel dowel that may have auxiliary parallel or nonparallel pins depending upon whether a one step (direct) or two step (indirect) procedure is used. Nonparallel pins provide increased retention for the composite-resin or amalgam core. Various sized engine reamers are provided to prepare the canal to the desired depth and diameter. Dowels are available in plastic, stainless steel or gold depending on the technique selected. Baraban has suggested that this system be employed for a single visit dowel and core placement.[27]

The third type of dowel is a stainless steel, threaded, tapered screw post which utilizes the axial dentin for retention. Standardized endodontic reamers or engine reamers which approximate the shape of the dowel are used for preparation. The dowel may be cemented or self-threaded into the canal lending additional retention. However, when using the self-threading mode, Caputo and Standlee warn that there can be potential root fracture.[28]

Landwerlen and Berry describe a technique where interestingly a dowel and core is constructed entirely from composite resin but not cast.[29] Here dowel space is made with a

*Whaledent International, New York, NY

bur and undercuts not eliminated. Pinholes for reception of T.M.S.* self-threading pins are drilled at strategic locations to achieve splinting across remaining tooth structure and to provide retention for the composite resin. Resin material is injected into the dowel space and then around the pins with a syringe.

Markely suggested the use of pins as an aid in gaining additional retention for coronal build-up with amalgam.[30] However, pins do not reinforce amalgam or composite restorations as described in studies by Going, et al.[31] In most cases restorations are weaker when pins are used. Pins that utilize the resiliency of dentin for their retention should not be used in endodontically treated teeth since installation stresses may result in damage to dentin as was shown by Standlee, et al.[32] This is important since endodontically treated teeth are seemingly more brittle.

There are advantages and disadvantages to these mentioned techniques and methods. According to Christy and Pipko, the poorest method is a cast-gold dowel core since the cast gold is in its most brittle form and will fracture unless it is thick or heat treated or both.[33] Their recommendation would be a combination of a high-fusing precious metal precision

*Whaledent International, New York, NY

dowel with a cast-gold core fitted to a well prepared dowel space.

Certain biomechanical principles must be followed for proper dowel placement. The dowel and core combination should provide the necessary strength as well as the proper retention form for the final restoration. Frank indicates that the retention of the dowel is proportional to the contact between the circumferential area of the dowel and the internal surface of the prepared canal.[18] According to Stern and Hirschfeld, the functional forces acting on the tooth should be optimally transferred from the coronal portion through the dowel and core to the radicular portion and supporting bone.[34] Thereby to achieve adequate resistance, dowel length is extremely important.

Various studies have considered the proper length of an inserted dowel. Lengths proposed have been: same length as the clinical crown; equivalent to the length of the anatomic crown; a minimum of one half the length of the root; one to one and one half times the length of the clinical crown; and one half to two thirds of the root length. However, length should not be gained at the expense of jeopardizing the apical seal of root canal obliterating material. Weine states that normally 3 to 5 mm of apical filling should remain.[24] These statements regarding length of dowel placed are really concerned only with retention and ignore the supporting bone structure and its importance in resisting root fracture.

Stern and Hirschfeld have observed that in most instances a tooth fractures diagonally from the coronal level to the margin of the supporting bone.[34] This is a result of forces acting upon a root unsupported by bone. A relatively short dowel with insufficient apical extension will more likely demonstrate this type of fracture. These investigators recommend that the apical extent of a dowel should reach a point which lies at least half way between the apex of the root and the alveolar crest of supporting bone. Therefore, whenever this minimum is impossible to obtain, a dowel is of little value.

Other parameters which influence the retention and protection potential of dowels include dowel design, channel configuration, insertion techniques and the choice of cements. These factors also relate to whether occlusal loads are distributed evenly through dentin to the periodontal ligament and supporting alveolar bone. Dowels which utilize the resiliency of dentin are obviously more retentive that those which are dependent on cement alone.

The dowel shape also has a pronounced effect on the supporting dentin. Standlee, et al. showed that tapered devices often exhibit a wedging effect which concentrates stress at the coronal portion of the dentin.[26] In addition the wedging effect will tend to split the root as Charlton observed.[35] These dowels also are the least retentive as was shown by Colley in his study on retention with dowels of different shapes and sizes.[36]

At a given diameter, the parallel-sided dowel offers maximum retention since there is a progressive loss of retention as divergence from parallel on the sides of the dowel is increased. Therefore, a parallel dowel will give as much retention as a longer, larger, tapered dowel. Parallel-sided dowels distribute occlusal loads more evenly to supporting structures as was reported by Standlee, et al.[26] Also a parallel-sided dowel transmits axial forces in line with the long axis of the tooth.

Colley warns that one must take into account the shape of the root and its canal when the root is small and narrow. The danger of perforating the root is great if a parallel-sided canal preparation is drilled into a narrow root.[36] Sickelmore suggested a tapered dowel which he thought was an ideal compromise since canal dentin was conserved.[37] Dowel diameter then should be as small as possible for a given clinical situation. One should attempt to gain dowel length and not rely upon width for needed retention since retention of a dowel increases as depth of embedment increases.[36,38]

C. Intracanal Heat Considerations

When dowel space preparations are performed in a tooth, certain reactions from heat and/or reaming may be possibly induced in the supporting periodontal ligament and alveolar bone. Orban describes the normal periodontal ligament as being composed of connective tissue fibers and cells, epithelial rests, blood vessels, lymphatics, and nervous supply.[39] The most important elements here are the collagenous or principal fibers which are in bundles and follow a wavy course. The portion of the principal fiber which is inserted into cementum or bone is termed Sharpey's fiber.

The principal fiber bundles are arranged in groups with some ramifying into the gingiva and others extending between approximating teeth. The majority of the fiber bundles lie between cementum and bone. Black originally described the distribution of the principal fibers.[40] Their description consists of two major classifications: transseptal fibers and alveolar fibers. The alveolar fibers can be subdivided into alveolar crest, horizontal, oblique and apical.

Transseptal fibers extend interproximally over the alveolar crest and are embedded in the cementum of adjacent teeth. These fibers are a remarkably constant finding, being present even when marked destruction of the alveolar bone has occurred. In the alveolar fibers, the alveolar crest group extend obliquely from the cementum just beneath the epithelial attachment to the alveolar crest. The function of these fibers is to counterbalance the coronal thrust of the more apical fibers thereby helping retain the tooth within its socket. The horizontal group extends at right angles to the long axis of the tooth from the cementum to the alveolar bone. Their function is similar to the alveolar crest group. The oblique group of fibers extends from the cementum in a coronal direction obliquely to the alveolar bone. This is the largest group of fibers and bears the forces of vertical masticatory stresses transforming them into tension on the alveolar bone. Fibers of the apical group radiate from the cementum of the tooth at the apex of the socket to the alveolar bone. In immature roots, these fibers are not observed.

Atrizadeh, et al. subjected the normal periodontium in squirrel monkeys to thermal injury via the root canal.[41] Intracanal heat was applied with a Coles Electrosurg* for a period of one second at an intensity of four. At three days and one week following the injury, an area of necrosis was found in the periodontal ligament which was circumferential, involved both periodontal ligament and alveolar bone, extended approximately one third the length of the root and did not

*Cole's Electronic Corp., Philadelphia, PA involve the epithelial attachment. Two and three weeks following thermal injury new fibroblasts and blood vessels were observed at the periphery of necrotic areas of which were progressively decreasing in size. Resorption of bone and cementum was also a prominent feature at this point. By one month, healing had proceeded to an extent that no necrotic tissue was present, bone apposition was more prominent than resorption, and in some areas osseous tissue had fused the experimental tooth to the alveolar bone. This ankylosis persisted for six months which was the time the study was concluded.

In the technique advocated by Schilder for obliteration of root canals, a hot instrument is used in the canal to manipulate gutta-percha for vertical condensation.[42] Because the Schilder "warm gutta-percha" technique has been only recently espoused, few studies have been made of the physical properties of gutta-percha when subjected to vertical condensation and heat. In one investigation, Marlin and Schilder made a determination of the distance to which the mass of gutta-percha would conduct heat ahead of heat application and vertical condensation.[43] Also of interest was the evaluation of volume stability of gutta-percha when used in a repeated sequence of heating and vertically condensing the material.

Teflon rods were used with a "root canal" machined into the material. Thermistors were chosen for heat determination and placed into holes drilled along the length of each rod so each was in contact with gutta-percha. Results showed that the temperatures recorded varied from a 12.5 degree C. increase in the gutta-percha in the body of the preparation to a 4.0 degree C. increase at the apex at the termination of condensation. The volume of gutta-percha recovered was significantly greater than the volume of the preparations.

An _in vitro_ and _in vivo_ study relative to the Schilder technique was conducted by Hand, _et al_.[44] They wanted to examine the microanatomy of the lateral periodontium subsequent to the introduction of hot instruments into the pulp canal. Miniature pigs were used for the _in vivo_ portion of the study. It was found that there were no deleterious changes inflicted upon the periodontium and supporting structures when histologic sections were examined. The _in vitro_ portion of the study utilized a thermocouple attached to both the external root surface of an extracted tooth and to a Schilder No. 0 heat carrier.* Temperature elevations detected at the outer surface of the root were 3-4 degrees C. Also the outer surface of the root returned to 37 degrees C. in approximately two minutes.

Gottlieb used surgical diathermy in root canal sterilization procedures where there was production of a great amount

*Star Dental Manufacturing Co., Inc., Conshohocken, PA of electric heat.[45] It was found that ankylosis, as well as root resorptions occurred regularly in the root canal treatment where this technique was used. Interestingly the same maladies could be observed when strong formalin solutions were placed in the canal.

D. Orthodontic Force Considerations

Rotation forces exerted on a tooth during brief reaming for dowel space preparation and its histological implication have not been investigated. More study though has been done on the associated tissue reaction when more prolonged orthodontic forces are maintained. Pure rotation of teeth is a reasonably complex procedure in which the center of rotation is the center of mass on the vertical axis. In a perfectly round root, the distance from the center of rotation to any point of the root is the same. In this situation, the tooth would rotate in the socket with no lateral or anteroposterior movement.

Various factors are involved in the movement of rotation. There are definite anatomical factors to be considered. Reitan stated that these are primarily related to the position of the tooth, its form, and size.[46] In most teeth that are to be rotated have roots that are more or less oval when viewed in cross section. Oval roots will create two pressure and two tension sides. The distance from the center of rotation to the farthest part of the root is greater than from the center of rotation to the middle area of the tooth. The circle thus transcribed by the outer aspect of the tooth is much larger, necessitating bone removal to accomodate the new position of the tooth.[47] It follows that for integrity of the alveolus to be maintained, bone formation occurs at the contralateral sites.

Another anatomical detail to be considered is the arrangement of the periodontal fibers. As is well known, the major group of periodontal fiber bundles runs from the root cementum to the inner alveolar bone. The free gingival fibers, however, are attached in the gingival soft tissues and the periosteum. Variation in the attachment of the fibers may play a role in retention of a new tooth position. Reitan found in his rotation studies that extensive changes occur in the alveolar bone with elongation of fiber bundles in the periodontal ligament as well as stretching and displacement of the free gingival fibers.[46] The rotated tooth then quite obviously must be retained while the rearrangement of these structures takes place. However, with brief hand or engine reaming in a root canal, periodontal fiber bundle rearrangement if it does occur, is not retained by any interposed mechanical means.

CHAPTER III

MATERIALS AND METHODS

The periodontal supporting tissue reaction to two methods of dowel space preparation was demonstrated in the following manner. Eight mongrel dogs approximately one year old were utilized for the investigation. They ranged in weight from 14.0 to 23.0 kilograms. The animals were housed and treated at the Loyola University Medical Center Animal Research Facility. The same treatment regimen was maintained for each experimental animal.

Each animal was premedicated in his cage prior to any procedure being performed. This consisted of an intramuscular injection of a 1.0 cc dose of Innovar-Vet.* Also at this time a 2.0 cc dose of atropine sulfate** (0.5 milligrams per cc) was injected subcutaneously to decrease oral secretions.

After the effects of the premedication were manifested, the dog was weighed and a foreleg shaved. For operating anesthesia, the radial vein was palpated and venipuncture performed whereupon sodium pentobarbital*** was injected intravenously to effect.

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*Pitman-Moore, Inc., Washington Crossing, NJ
**Burns-Biotec, Oakland, CA
***W.A. Butler Co., Columbus, OH

The dose utilized was 1.0 cc for each 2.5 kilograms of body weight. The animal was secured to the operating table and a spring-retained mouth prop interposed between the maxillary and mandibular canine teeth. Pretreatment radiographs of the maxillary and mandibular incisors were taken and developed.

The anterior teeth, control as well as experimental, were swabbed with a 70% alcohol and 2X2 cotton gauze sponges were placed in the facial vestibule. Isolation of teeth was achieved by gauze packs, the mouth prop, and the use of atropine sulfate. Occlusion was reduced on all anterior teeth with a crosscut fissure bur in an ultra-speed dental handpiece. Following this, access cavity preparations were completed on the experimental teeth exposing the coronal pulps.

Pulp canal contents were broached and either a #15 or a #20 K file* was placed in each experimental canal. Radiographs were taken and working lengths determined. Canals were instrumented according to clinically accepted procedures with canal preparation being terminated at three instruments beyond the first size that bound at the working length. The distribution of the experimental variables is listed in Tables I and II. During canal preparation, debris was flushed and lubrication provided by the utilization of copious amounts of a 5.25% sodium hypochlorite solution. Final instrument sizes

*Union Broach Corp., Long Island City, NY and lengths were recorded.

Following intracanal instrumentation, the canals were irrigated and dried by absorbent paper points. The teeth were then obliterated with gutta-percha* and Proco-Sol** sealer using a lateral condensation method, as described by Weine.[14] Cotton was placed in each tooth followed by condensation of amalgam for effecting an occlusal seal. Both maxillary and mandibular teeth were operated at one treatment sitting. The dog was then returned to the housing area for recovery. No diet restrictions were imposed.

Thirty days following canal obliteration, access was again gained and space was prepared using either hand or engine preparation. The engine preparation was accomplished by the use of graded Peeso reamers*** in a low-speed contra-angle for gutta-percha removal and canal enlargement. The hand technique involved softening of gutta-percha with a red hot Luks plugger*** so that the gutta-percha adhered to the plugger and was withdrawn from the canal. Hand reamers were then used in sequential order employing reaming action to enlarge the canal. The dowel space preparation was terminated such that approximately 3 mm of gutta-percha remained in the apical segment of the canal. Debris was cleaned from the teeth and the

*Mynol Chemical Co., Broomall, PA
**Proco-Sol Chemical Co., In., W. Conshohoken, PA
***Union Broach Corp., Long Island City, NY

amalgam seal replaced.

Following dowel space preparation procedures, two dogs were sacrificed at 1 day, three dogs at 7 days and three dogs at 30 days. An intravenous injection (8-10 cc) of Beuthanasia-D* was administered to each animal. The maxilla and mandible were removed distal to the canine with a cast saw. The resultant blocks were immediately placed in a 10% neutral buffered formalin solution. Shortly thereafter the blocks were trimmed with a water cooled crosscut fissure bur in an ultra-speed dental handpiece. The specimens were then returned to the formalin solution for a fixation period of 30 days and then rinsed in running water for 24 hours.

A sodium citrate-formic acid solution was used to decalcify the specimens. During decalcification, the specimens were further trimmed and sectioned into tooth-sized blocks suitable for embedding. The blocks were sectioned either longitudinally or horizontally. Decalcification was completed in fifty to sixty days and a thorough water rinse followed. The trimmed blocks were dehydrated in ethanol, embedded in paraffin, and sectioned at 6 microns. Every tenth section from serial sections was mounted on a glass slide. The sections were deparaffinized, hydrated and stained with hematoxylin and eosin.

*Burns-Biotec Laboratories, Oakland, CA

Stained histologic sections were examined using a light microscope. The lateral periodontium was evaluated for the presence of inflammation and changes associated with hyalinization as well as for alveolar bone resorption. Root resorption was recorded in addition to observation of the remaining contents of the pulp canal. The presence of periapical pathosis was also noted. This information is provided in Tables III through X.

CHAPTER IV

RESULTS

A. General

The animals were examined periodically for general health maintenance during the study. All remained healthy and at the time of sacrifice they exhibited some gain in weight. The amalgam seals that had been placed were intact with no fractures evident. No draining sinus tracts could be observed upon soft tissue examination.

Pretreatment and posttreatment radiographs were examined for the detection of changes in the periodontal ligament or the development of areas of bone rarefaction. No teeth of any animal developed periapical or lateral areas of rarefaction that could be observed radiographically during the study. Also, those teeth which radiographically demonstrated periapical rarefied areas at the start of treatment still had them at the time of sacrifice. The continuity of the lateral periodontal ligament was maintained in all experimental teeth as verified by radiographs.

B. Histology

A microscopic analysis of the histologic sections revealed no differences in periodontal tissue response between the two methods of dowel space preparation. This was true at all experimental time intervals studied with no pathological changes different from the controls observed in any of the teeth.

There was a complete absence of inflammation in the lateral periodontal ligament of all dogs. In general, the periodontal ligaments observed consisted of dense collagenous fibers running from cementum to alveolar bone with no stretching or rearrangement of the fibers. Visible among the collagen fibers were interstitial spaces. Prominent within these spaces were numerous blood vessels, often congested with erythrocytes (Figure 1). This arrangement was found in all tooth specimens observed. Fibroblasts were found in abundance with a few epithelial cell rests encountered. Changes associated with hyalinization of the periodontal ligament were not a finding in any of the teeth examined.

In control as well as the experimental teeth, osteoclasts were present in all sections (Figures 2 and 3). Often they were seen on the periphery of the alveolar bone residing in Howship's lacunae. There appeared to be no specificity as to their location since they were found anywhere from the alveolar crest to the apex of the tooth. Osteoblasts were seen in sections, presumably laying down osteoid (Figure 4). In addition, viable osteocytes were observed in the alveolar bone proper.

The root structures of the teeth were covered with cementum which varied in thickness. Most frequently the thickness increased from the cervical region to the apical region. A thin layer of cementoid tissue was also present on the surface of the cementum. In addition, cementoblasts were observed within this tissue.

On the lateral aspects of the roots of six teeth were found areas of root resorption (Figures 5 and 6). In some cases it was confined to the cementum and in others it was penetrating into the dentin. This pattern was observed in both control and experimental teeth. In some of the areas, the surface resorption was being repaired with new cementum.

In eleven of the teeth examined histologically, including both controls and experimentals, periapical granulomas were found (Figure 7). Also, they were observed radiographically in both preoperative and sacrifice radiographs. A representative granuloma was composed of granulation tissue, fibroblasts, and collagen fibers with an edematous fibrous connective tissue stroma. Plasma cells, macrophages, and lymphocytes were included in the cellular infiltration with a lesser number of polymorphonuclear leucocytes dispersed throughout the lesion. Also seen in the area were extravasated erythrocytes. The presence of epithelial tissue was an uncommon finding. The entire granuloma was encapsulated in varying degrees by dense collagen fiber bundles and in some sections, abscessing was occurring within the lesion. In those sections where granulomas were present, cementum resorption was observed at the apex of the roots.

The canal contents varied according to the experimental treatment performed. In unoperated control teeth, normal pulp tissue or tissue fragments were found (Figure 8). The remaining teeth had gutta-percha condensed into prepared canals, some of which had a portion of the gutta-percha removed for dowel space preparation. In others, the gutta-percha remained as operated controls. In either situation, the canals exhibited varying quantities of residual sealer and dentin chips with no gutta-percha remaining due to histologic preparation. In some sections where dowel space was prepared, a definite demarcation between it and canal preparation was discernible (Figure 9). Also, no internal resorption was observed in any tooth whether it was a control or experimental tooth specimen.

CHAPTER V

DISCUSSION

A. General

In this clinical study, the two techniques employed for preparation of dowel space did not damage the integrity of the lateral periodontal structures. All histologic structures observed were within normal limits when compared to control specimens. If any changes were manifested, they were not observable in the tissues at the microscopic level. Perhaps some histochemical changes may have occurred but these were not detected by the present means of evaluation of tissue response.

With a comparison to human tissue, the dog has a similar arrangement of supporting structures.[46] The changes taking place in the alveolar bone are also quite similar. The periodontal fibers, however, are coarser in the dog than man and the bone tissue in the dog is frequently denser.

In retrospect to selection of teeth for dowel space preparation, the maxillary teeth offer a more direct correlation to human sizes than do the mandibular teeth. Also, instrumentation is easier on the maxillary teeth and roots are farther apart in the bone for better visualization and histologic separation.

With the intracanal preparation of any tooth, dowel space preparation included, one must be extremely aware of root canal morphology and its implications. At times there is a tendency to over-prepare teeth with engine driven reamers due to the ease of manipulation and lack of tactile sensation. Teeth that possess proximal concavities in their anatomy present a very real hazard with the engine technique, especially when large-sized instruments are used. The straight-on view on a radiograph is deceiving since areas of reduced tooth bulk are not readily observable. Also, engine reamers are seldom entirely "true" and have a tendency to whip laterally engaging excess lateral tooth structure. The addition of operator induced force and undesirable angulation, can possibly lead to perforation of a root. In addition, there is a tendency at times to become undercut when using engine reamers if care is not exercised.

When examining the periodontal ligament of the dogs, many blood vessels were observed and they were often congested with erythrocytes. In addition, osteoclasts were present in the alveolar bone of the control as well as experimental teeth. Bone is never a static tissue and is continuously undergoing remodeling according to functional needs. This necessitates special care in differentiating between normal and abnormal from external force application. Khouw and Goldhaber made an interesting observation in regards to the vessel density in the normal periodontal ligament of the dog.[48] They indicated that the connective tissue next to the bone has a richer blood supply than that next to the cementum. This might account for the greater reactivity of bone with respect to remodeling as compared to cementum.

Root resorptions were observed in a very limited number of control as well as experimental teeth. In some instances the resorptions extended beyond the cementum into dentin. These resorptions have been demonstrated frequently in normal human permanent teeth and in accidentally traumatized teeth.[49,50] Animal experiments have revealed that external root resorption is a common finding in connection with various experimental traumas and loadings of the teeth, such as orthodontic tooth movement and traumatic occlusion.[51,52] Replantation procedures are also associated with external root resorption. Andreasen and Hjorting-Hansen described the three different kinds of external root resorption.[53] These were surface resorption, inflammatory resorption and replacement resorption. In the present investigation, the voids observed would have to be classified as surface resorption since no inflammation was observed in the periodontal structures. Andreasen also described surface resorption being associated with accidental luxation of human teeth.[50] As stated, root resorption has been shown to occur in healthy teeth. However, it occurs more often in periodontally diseased teeth.[54] This observation was further supported by Dragoo and Sullivan who observed external root resorption associated with chronic inflammation in the adjacent gingiva.[55] Thus, the few random occurrences of root resorption in the present investigation could be attributed to a number of etiologic events with trauma, periodontal disease, or idiopathic entities being distinct possibilities.

B. Heat Considerations

In histologic response, the present study compares favorably to the work done by Hand and associates, where the lateral periodontium was examined following procedures preparatory to vertical condensation of gutta-percha.[44] In Hand's study, plunging a heat carrier that had been heated in the flame of a laboratory burner into a fitted gutta-percha master point in the canal, produced only slight inflammation at the 1-, 3-, and 4-hour experimental specimens in miniature pigs. No inflammation was found at sacrifice periods of 12, 24, 48, and 72 hours. These individuals also recorded the temperature of the heat carrier by using a thermocouple with leads connected to a multichannel recording device. It was found that the temperature of the heated instrument declined 90 degrees C. to 370 degrees C. before contact with gutta-percha was made. With an *in vitro* temperature measurement of the outer surface of the tooth root done, it was found that there was a rise of 4 degrees C. after the heat carrier was placed into the gutta-percha and allowed to contact a canal wall. In about two minutes the root surface returned to 37 degrees C. From the *in vitro* studies, it was observed that the conduction of heat from the gutta-percha to the canal walls can proceed at a relatively fast rate as the temperature rise in the outer root surface was elicited in less than one minute. Temperature changes occurring at the outer root surface would appear to be small. The authors further indicated that if small quantities of heat are transmitted to the periodontal structures, it would be dissipated by the vasculature.

When analyzing the above work, the temperatures measured must be considered relative since the thermocouple was attached 15 mm from the pointed end of the heat carrier. Also, the thermocouple placed on the outer root surface was approximately 10 mm away from the final resting place of the end of the heat carrier. In conclusion, the heat change to the root was considered small since no deleterious changes were noted.

In the present study utilizing dogs, a plugger was used as the heat carrier upon which the gutta-percha adhered and could be withdrawn from the canal. This type of plugger is of a larger diameter and thereby requires a longer time to heat but also takes longer for the heat to dissipate. However, these pluggers are not thrust deeply into the gutta-percha or are they held there for a long period of time. Multiple, shallow penetrations are effected until the correct depth is reached with minimal contact of canal walls. It would seem that this technique would inflict minimal harm to the lateral periodontium as was evidenced by the results obtained.

In the study by Atrizadeh and co-workers, thermal injury to the periodontium was the intention such that necrosis resulted and eventual ankylosis developed.[41] With a smooth broach attached, an electrosurgery scalpel was introduced into the canal. Enhancement of thermal conductivity to the periodontal structures was provided by a toothpaste conducting aid and direct placement of the broach upon a canal wall. An intensity of four for one second produced the tissue damage. Here there was no insulating gutta-percha, only dentin. The thermal irritant placed in the canal overpowered any insulating properties of dentin. Thereby, one can exceed the limits of the host defense with the proper intensity and duration of the insult.

One may question if the gutta-percha apical to the prepared dowel space could act as a reservoir of heat.

Marlin and Schilder provided some information from an in vitro study.[43] In the vertical condensation method of obliterating a root canal as advocated by Schilder, repeated penetrations of the gutta-percha with the heat carrier and vertical plugging is done until the apical third of the canal is reached. It was found that a 4 degree C. temperature increase occurred after eleven minutes. This increased temperature persisted for fifteen minutes after apical sealing. Gutta-percha has a very low thermal conductivity and the authors indicated that the temperature increase was so small that it is clinically insignificant.

Gutta-percha may be thought of as a thermal insulator for the periodontal structures. In industry, Ernst Werner von Siemens in 1848 used gutta-percha for the first successful insulation for an underwater line.[56] Also, gutta-percha was considered the most desirable insulator of electric cables until its replacement by vulcanized rubber late in the 19th century. Therefore, with the thermomanipulation of gutta-percha in vertical condensation or dowel space preparation, there is some gutta-percha and sealer that is interposed between the heat carrier and dentin wall quite possibly effecting some type of thermal insulation.

From the thermal conductivity measurements of several investigators, dentin itself has been found to be an effective thermal insulator.[57-60] Thermal insults to the axial dentin within a canal may be dissipated and reduced by its relatively unfavorable thermal conductivity. The quality of the dentin itself will also have a direct effect on resulting conductivity. Fanibunda and de Sa found that the mean thermal conductivity of dehydrated dentin was 7.6 per cent lower than normal tubular dentin.[60] This is because the water content of the dentinal tubules is now replaced by air. Also, sclerotic dentin with fewer tubules has a reduced available water content and thereby reduced thermal conductivity. Thus, the insulating properties of dentin will vary not only with the quality of dentin present and the stimulus it receives, but also with respect to age. Age may be protective to the supporting periodontal structures if heat is to be used in the canal. This protection may arise from the reduced hydration associated with endodontically treated teeth and the increased incidence of sclerotic dentin in the root both contributing to increased thermal insulation or reduced conductivity. Therefore, the lateral periodontium can be insulated and afforded protection from insults placed within a canal from the thermal insulating properties of both gutta-percha and dentin.

C. <u>Orthodontic Force Considerations</u>

The rotation forces applied to the experimental teeth were either by hand reaming action or by low-speed contra-angle action. Both methods involved application of force for only a brief duration of time. However, when using hand reaming action it is possible that there is more tendency to exert increased rotational forces upon the tooth. This may occur in the reaming sequence when the next larger instrument binds to an extent and increased rotary manipulation is required to overcome the frictional resistance met. In the contra-angle procedure, the tendency is for the engine reamer to stall-out permitting no rotation against increased resistance. Going back to a smaller instrument will solve the problem with each given procedure. Also, if the cutting instrument of either hand or engine is dull, more trauma may be inflicted to the supporting structures.

The periodontal ligament has the capacity to dissipate applied forces inflicted upon the tooth. Boyle stated that the absorption of forces occurred by vascular channels cushioning the hydraulic pressure thus allowing gradual extension of the fibers.[61] Further absorption occurred via the morphology of the teeth and resiliency of the dentin. Bien later described the hydraulic dampening effect more thoroughly.[62] He stated there were three separate but interacting systems. First the interstitial fluid between the cells, vessels, and fibers is involved; then the vascular system intercedes to dampen the pressure. If the pressure continues a third fluid system, periodontal ligament cells and fibers, would attempt the absorption. There, excessive force beyond physiologic limits will embarrass the blood supply and cause necrosis. Also, as Muhlemann indicated, in small movements of the tooth only the periodontal ligament is distorted.[63] For larger movements, the alveolar bone can also be distorted.

Daly and co-workers performed an <u>in vivo</u> test to measure the response of the periodontal ligament to torsional loading.[64] The loads were applied to five human maxillary central incisors using a torque loading device incorporating an electronic servo system. Responses in the periodontal ligament were recorded on a chart recorder. In rotating a tooth one degree in various tests, it was shown that a commonly found decrease in tissue stiffness during the initial few load cycles is not a permament effect. Recovery to the initial stiffness takes place rapidly, e.g. 50 per cent recovery in five minutes at zero load. Therefore, in the successive loads applied in the reaming action in preparing dowel space in a tooth, possibly recovery can be attained rather quickly once zero load is reached.

With the application of a magnitude of force to a tooth for a given period of time, definite histologic changes in the periodontal tissues are manifested. In tooth tipping experiments with rat molars, Macapanpan, et al., reported significant numbers of mitotic figures in fibroblasts on the tension side two hours after the application of force.[65] They also reported hyalinization on the pressure side one hour after the force had been applied. Zaki and Van Huysen, studying early histologic changes in the periodontal tissues following the application of force to rat molars, found similar reactions on pressure and tension sides.[51] In addition, tissue changes accompanying the experimental tooth movement, whether on the tension or pressure sides, were devoid of any signs of inflammation.

Kuftinec, using hamsters, demonstrated changes in vasculature during experimental tooth movement.[66] Early changes on the tension side were a wider than normal periodontal ligament and more blood vessels of greater caliber. The pressure surfaces were in virtual contact with the alveolar bone, and all vessels were completely obstructed. As time went on, vascular reorganization towards normal was occurring on both sides. The above studies involved force applications of thirty minutes to several hours. Therefore, changes associated with hyalinization and stretched periodontal ligament fibers and cellular proliferation have heretofore been found after more lengthy periods of magnified force application than that utilized in the present study. This was very clearly shown in the results with no observable tissue changes noted.

If hyalinization occurs, normal architecture of the periodontal ligament is lost. Most of the nuclei disappear and some few remaining nuclei show deep staining or pyknosis. The principal fibers and interstitial tissue disappear, leaving a clear, homogeneous, pale, eosin-staining, structureless material. In the periodontal structures of the experimental dogs used, distinct fibers, fibroblasts and vascularity were always clearly evident.

From the results of this investigation, one could state that no vital structures were compromised with either technique used for dowel space preparation which was in agreement with Hand, et al.[44] The applied stimuli were within the physiologic limits of the test animal utilized. Moreover, the heat and reaming forces used were of a magnitude and duration common to the clinical practice of dowel space preparation. The lateral supporting structures of the teeth were not adversely affected due to natural anatomic and physiologic insulation and cushioning mechanisms of the dentin, gutta-percha and periodontal ligament. Therefore, it definitely appears that dowel space preparation by either of these two methods is quite compatible with the lateral supporting periodontal structures.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The response of the lateral periodontal supporting tissue to two methods of dowel space preparation was studied. One technique for gutta-percha removal and dowel space preparation consisted of utilizing Peeso reamers in a low-speed contra-angle handpiece. The other technique employed a hot plugger for gutta-percha removal with sequential hand reaming used for final canal enlargement. The anterior teeth of eight dogs were used for the study. Both the maxillary and mandibular teeth of each animal were divided up into control and experimental specimens. Conventional endodontics was completed and after thirty days, specified teeth had dowel space prepared by one of the two techniques. After the completion of dowel space preparation, dogs were sacrificed at one day, seven days, and thirty days. The results of this study led to the following conclusions:

(1) Under the clincial conditions of this study, the two methods of dowel space preparation initiated no observable inflammation or histologic changes in the lateral periodontium.

(2) Dentin and gutta-percha provide a thermal insulating barrier for the lateral periodontium during the brief

placement of intracanal heat from a hot plugger.

(3) Reaming, whether by hand or engine means, caused neither stretching, rearrangement, or hyalinization of the periodontal ligament fibers.

(4) Alveolar bone remodeling is a dynamic process and must not be confused with the resultant effects of an experimental procedure.

CHAPTER VII

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CHAPTER VIII

APPENDIX

A. TABLES - B. FIGURES

Symbols used in TABLES III through X:

GC = gutta-percha control

C = unoperated control

H = hand preparation

E = engine preparation

U = maxillary teeth

L = mandibular teeth

PDL = periodontal ligament

PA = periapical granuloma

XS = cross-section

LG = longitudinal section

+ = present

0 = not present

TABLE I

DISTRIBUTION OF TREATMENT MODALITIES FOR EACH DOG

Dog	A	B	C	D	E	F	G	H
Maxillary	H	E	H	E	Mix	E	H	H
Mandibular	E	H	E	H	Mix	H	E	*
Sacrifice (days)	1	1	7	7	7	30	30	30

TABLE II

DISTRIBUTION OF VARIABLES FOR INDIVIDUAL TEETH

Maxillary and Mandibular Incisors

Right	1	2	3	4	5	6	Left
	GC	C	H or E	C	H or E	C	

*Mandibular teeth were inoperable.

TABLE III

HISTOLOGIC RESULTS - DOG A

Incisor	Sect.	PDL Infl.	PDL Hyal.	Alv. Bone Resorption	Root Resorption Lateral	Root Resorption Apex	PA Gran.	Canal Contents
UGC	LG	0	0	+	0	0	0	Sealer, dentin chips
UC	LG	0	0	+	0	0	+	Pulp strands
UH	LG	0	0	+	+	+	+	Sealer, dentin chips
UC	LG	0	0	+	0	0	+	Pulp strands
UH	LG	0	0	+	0	0	+	Sealer, dentin chips
UC	LG	0	0	+	0	0	0	Normal pulp tissue
LGC	LG	0	0	+	0	0	0	Residual sealer
LC	LG	0	0	+	0	0	0	Normal pulp tissue
LE	LG	0	0	+	0	0	0	Sealer, dentin chips
LC	LG	0	0	+	0	0	0	Normal pulp tissue
LE	LG	0	0	+	0	0	0	Residual sealer
LC	LG	0	0	+	0	0	0	Normal pulp tissue

TABLE IV

HISTOLOGIC RESULTS - DOG B

Incisor	Sect.	PDL Infl.	PDL Hyal.	Alv. Bone Resorption	Root Resorption Lateral	Root Resorption Apex	PA Gran.	Canal Contents
UGC	LG	0	0	+	0	0	0	Sealer, dentin chips
UC	LG	0	0	+	0	0	0	Normal pulp strands
UE	LG	0	0	+	0	0	0	Sealer, dentin chips
UC	LG	0	0	+	0	0	0	Normal pulp strands
UE	LG	0	0	+	0	0	0	Sealer, dentin chips
UC	LG	0	0	+	0	0	0	Empty
LGC	LG	0	0	+	0	0	0	Sealer, dentin chips
LC	LG	0	0	+	0	0	0	Normal pulp tissue
LH	LG	0	0	+	0	0	0	Sealer, dentin chips
LC	LG	0	0	+	0	0	0	Normal pulp strands
LH	LG	0	0	+	0	0	0	Sealer, dentin chips
LC	LG	0	0	+	0	0	0	Normal pulp tissue

TABLE V

HISTOLOGIC RESULTS - DOG C

Incisor	Sect.	PDL Infl.	PDL Hyal.	Alv. Bone Resorption	Root Resorption Lateral	Root Resorption Apex	PA Gran.	Canal Contents
UGC	LG	0	0	+	0	0	0	Sealer, dentin chips
UC	LG	0	0	+	0	0	0	Normal pulp tissue
UE	LG	0	0	+	0	0	0	Mostly empty
UC	LG	0	0	+	0	0	0	Empty
UE	LG	0	0	+	0	0	+	Empty
UC	LG	0	0	+	0	0	0	Normal pulp strands
LGC	LG	0	0	+	0	0	0	Residual sealer
LC	LG	0	0	+	0	0	0	Normal pulp strands
LH	LG	0	0	+	0	0	+	Sealer, dentin chips
LC	LG	0	0	+	0	0	+	Mostly empty
LH	LG	0	0	+	0	0	0	Mostly empty
LC	LG	0	0	+	0	0	0	Empty

TABLE VI

HISTOLOGIC RESULTS - DOG D

Incisor	Sect.	PDL Infl.	PDL Hyal.	Alv. Bone Resorption	Root Resorption Lateral	Root Resorption Apex	PA Gran.	Canal Contents
UGC	LG	0	0	+	0	0	0	Sealer, dentin chips
UC	LG	0	0	+	0	0	0	Normal pulp tissue
UH	LG	0	0	+	0	0	+	Sealer, dentin chips
UC	LG	0	0	+	0	0	0	Normal pulp tissue
UH	LG	0	0	+	0	0	0	Residual sealer
UC	LG	0	0	+	0	0	0	Normal pulp strands
LGC	LG	0	0	+	0	0	0	Residual sealer
LC	LG	0	0	+	0	0	0	Normal pulp tissue
LE	LG	0	0	+	0	0	0	Sealer packed at apex
LC	LG	0	0	+	0	0	0	Empty
LE	LG	0	0	+	0	0	0	Sealer, dentin chips
LC	LG	0	0	+	0	0	0	Normal pulp tissue

TABLE VII

HISTOLOGIC RESULTS - DOG E

Incisor	Sect.	PDL Infl.	PDL Hyal.	Alv. Bone Resorption	Root Resorption Lateral	Root Resorption Apex	PA Gran.	Canal Contents
UGC	XS	0	0	+	0	0	0	Sealer, dentin chips
UC	XS	0	0	+	0	0	0	Normal pulp tissue
UE	XS	0	0	+	0	0	0	Sealer, dentin chips
UC	XS	0	0	+	0	0	0	Normal pulp tissue
UH	XS	0	0	+	0	0	0	Sealer, dentin chips
UC	XS	0	0	+	0	0	0	Normal pulp strands
LGC	XS	0	0	+	+	0	0	Residual sealer
LC	XS	0	0	+	+	0	0	Normal pulp tissue
LE	XS	0	0	+	0	0	0	Residual sealer
LC	XS	0	0	+	0	0	0	Normal pulp tissue
LH	XS	0	0	+	+	0	0	Residual sealer
LC	XS	0	0	+	0	0	0	Normal pulp tissue

TABLE VIII

HISTOLOGIC RESULTS - DOG F

Incisor	Sect.	PDL Infl.	PDL Hyal.	Alv. Bone Resorption	Root Resorption Lateral	Root Resorption Apex	PA Gran.	Canal Contents
UGC	XS	0	0	+	0	0	0	Sealer, dentin chips
UC	XS	0	0	+	0	0	0	Normal pulp strands
UE	XS	0	0	+	+	+	+	Sealer, dentin chips
UC	XS	0	0	+	0	0	0	Normal pulp tissue
UE	XS	0	0	+	0	0	0	Mostly dentin chips
UC	XS	0	0	+	0	0	0	Normal pulp tissue
LGC	XS	0	0	+	0	0	0	Residual sealer
LC	XS	0	0	+	0	0	0	Normal pulp strands
LH	XS	0	0	+	0	0	0	Sealer, dentin chips
LC	XS	0	0	+	0	0	0	Normal pulp tissue
LH	XS	0	0	+	+	0	0	Empty
LC	XS	0	0	+	0	0	0	Normal pulp tissue

TABLE IX

HISTOLOGIC RESULTS - DOG G

Incisor	Sect.	PDL Infl.	PDL Hyal.	Alv. Bone Resorption	Root Resorption Lateral	Root Resorption Apex	PA Gran.	Canal Contents
UGC	LG	0	0	+	0	0	0	Sealer, dentin chips
UC	LG	0	0	+	0	0	0	Normal pulp tissue
UH	LG	0	0	+	0	0	0	Residual sealer
UC	LG	0	0	+	0	0	0	Empty
UH	LG	0	0	+	0	+	+	Sealer, dentin chips
UC	LG	0	0	+	0	0	0	Normal pulp tissue
LGC	LG	0	0	+	0	0	0	Residual sealer
LC	LG	0	0	+	0	0	0	Normal pulp strands
LE	LG	0	0	+	0	+	+	Sealer, dentin chips
LC	LG	0	0	+	0	0	0	Normal pulp tissue
LE	LG	0	0	+	0	0	0	Dentin chips
LC	LG	0	0	+	0	0	0	Normal pulp tissue

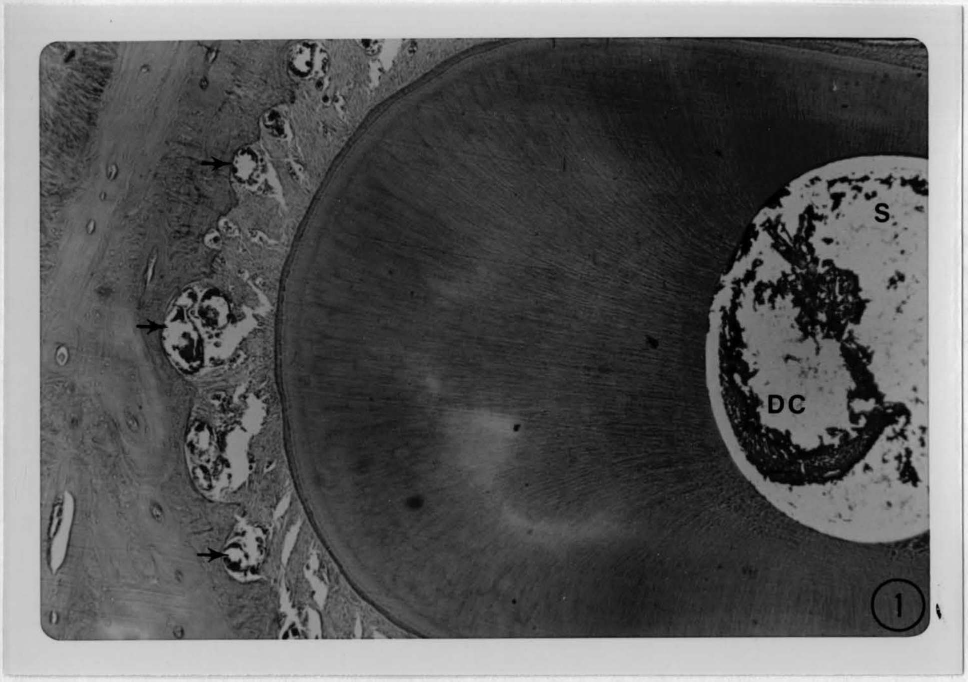
TABLE X

HISTOLOGIC RESULTS - DOG H

Incisor	Sect.	PDL Infl.	PDL Hyal.	Alv. Bone Resorption	Root Resorption Lateral	Root Resorption Apex	PA Gran.	Canal Contents
UGC	LG	0	0	+	0	0	0	Residual sealer
UC	LG	0	0	+	0	0	0	Normal pulp strands
UH	LG	0	0	+	0	0	0	Sealer, dentin chips
UC	LG	0	0	+	0	0	0	Empty
UH	LG	0	0	+	0	0	0	Sealer, dentin chips
UC	LG	0	0	+	0	0	0	Normal pulp tissue

Figure 1: Engine preparation, seven days. Numerous congested blood vessels appear in the periodontal ligament (arrows) as well as residual sealer (S) and dentin chips(DC) within the canal. (Cross-section, hematoxylin and eosin stain. Original magnification, X25)

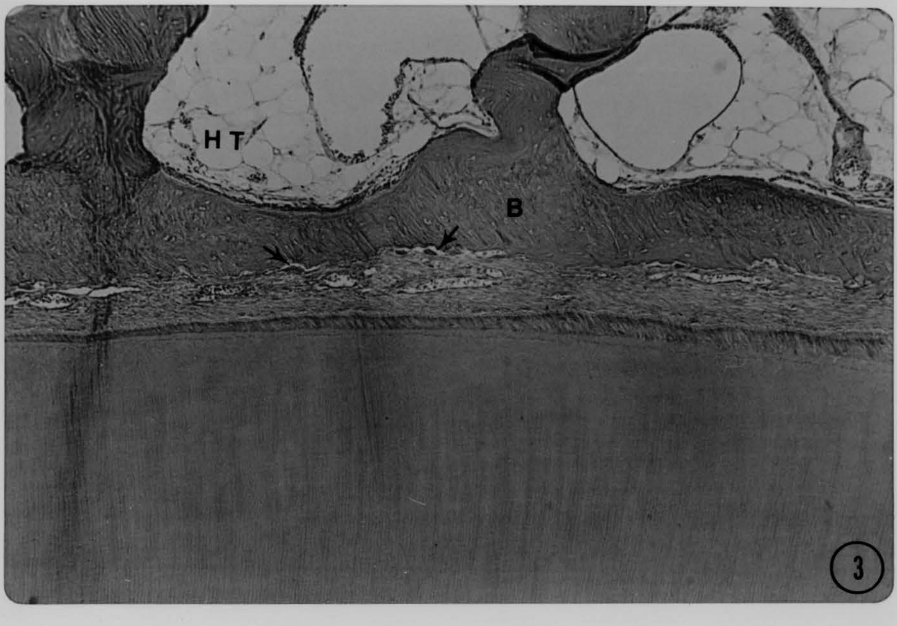
Figure 2: Unoperated control, one day. Remodeling resorption (arrows) taking place in the alveolar bone (B). Note normal non-inflamed periodontal ligament (PDL) and adjacent cementum (C) and dentin (D). (Longitudinal section, hematoxylin and eosin stain. Original magnification, X40)


S
DC
1

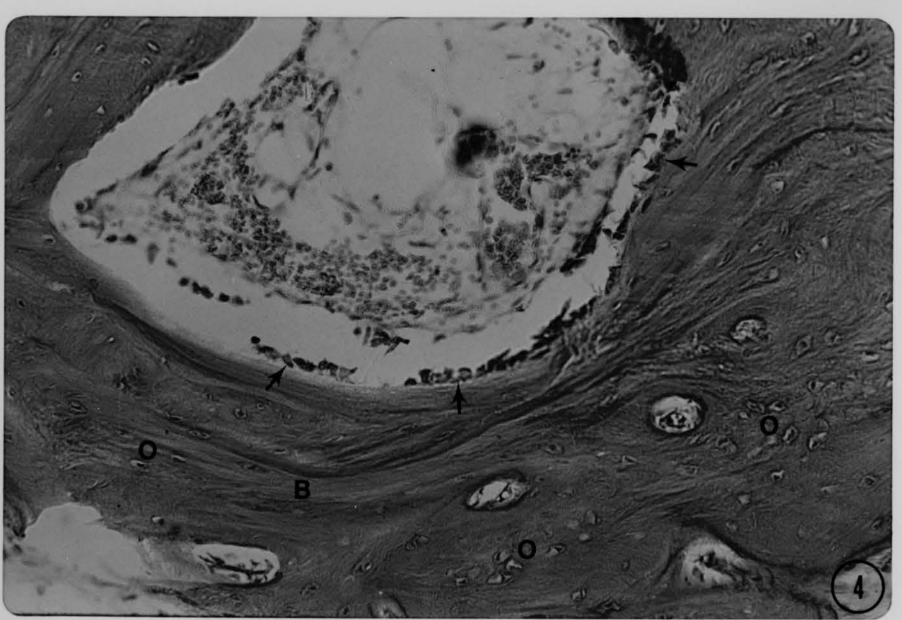

PDL
C
D
B
2

Figure 3: Hand preparation, seven days. Remodeling resorption (arrows) occurring as in Figure 2. Also visible is hemopoietic tissue (HT) with fatty infiltration within the alveolar bone (B). (Longitudinal section, hematoxylin and eosin stain. Original magnification, X40)

Figure 4: Hand preparation, one day. Osteoblasts (arrows) presumably laying down osteoid material. Osteocytes (O) can be observed in the alveolar bone proper (B). Longitudinal section, hematoxylin and eosin stain. Original magnification, X100)



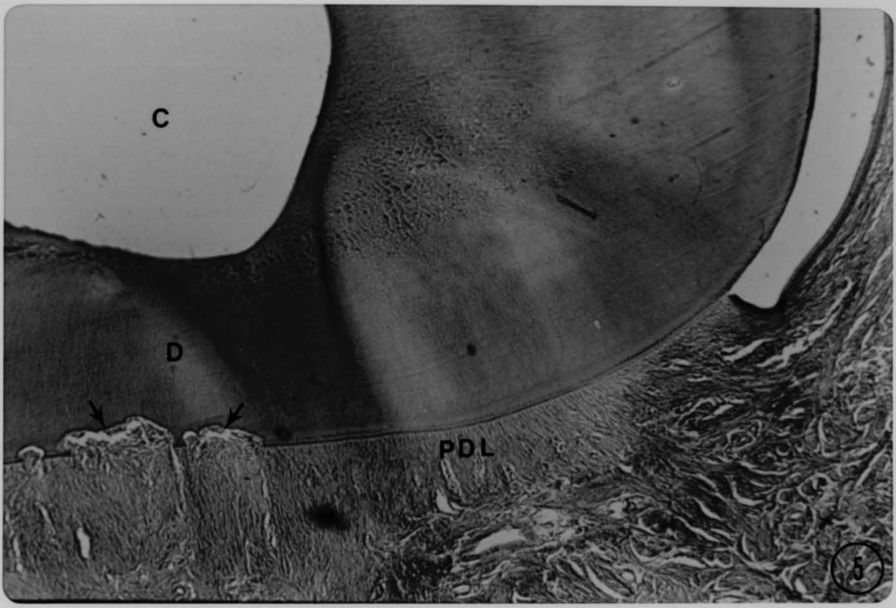
HT
B
3



O
B
O
O
4

Figure 5: Hand preparation, thirty days. Root surface resorption (arrows) extending into the dentin (D). Note adjacent periodontal ligament fibers (PDL) and empty canal (C). (Cross-section, hematoxylin and eosin stain. Original magnification, X25)

Figure 6: Hand preparation, thirty days. Resorptive cell (arrow) observed in a resorption lacuna in the dentin (D). (Cross-section, hematoxylin and eosin stain. Original magnification, X40)


C
D
PDL
5

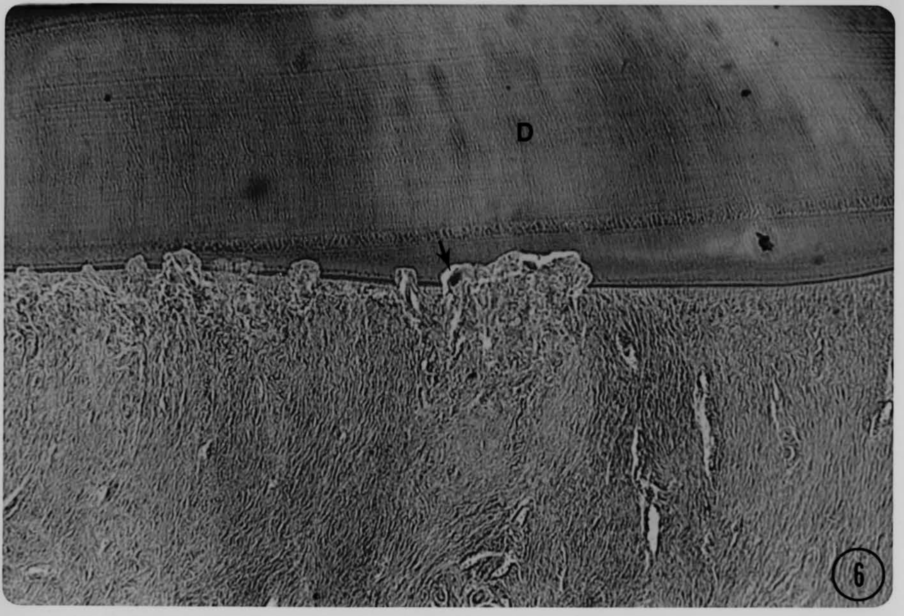
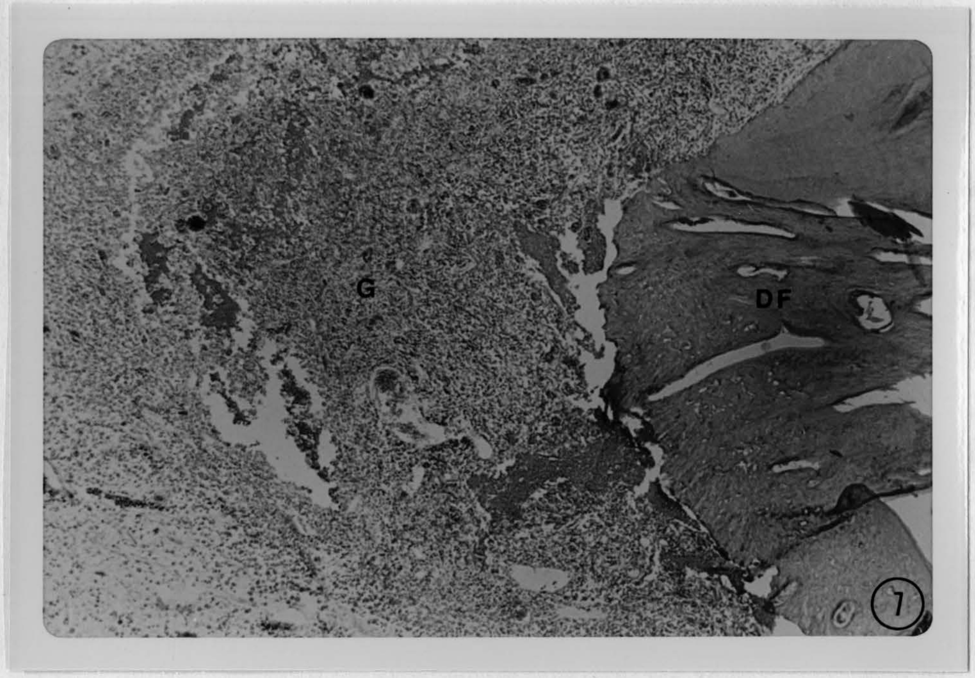

D
6

Figure 7: Unoperated control, one day. Periapical granuloma (G) with abscess formation (arrow) occurring within the lesion. Note delta formation (DF) at the apex of the tooth. (Longitudinal section, hematoxylin and eosin stain. Original magnification, X25)

Figure 8: Unoperated control, thirty days. Normal pulp tissue within the canal. Note predentin (arrow) and connective tissue stroma (CT) present. (Cross-section, hematoxylin and eosin stain. Original magnification, X40)


G
DF
7

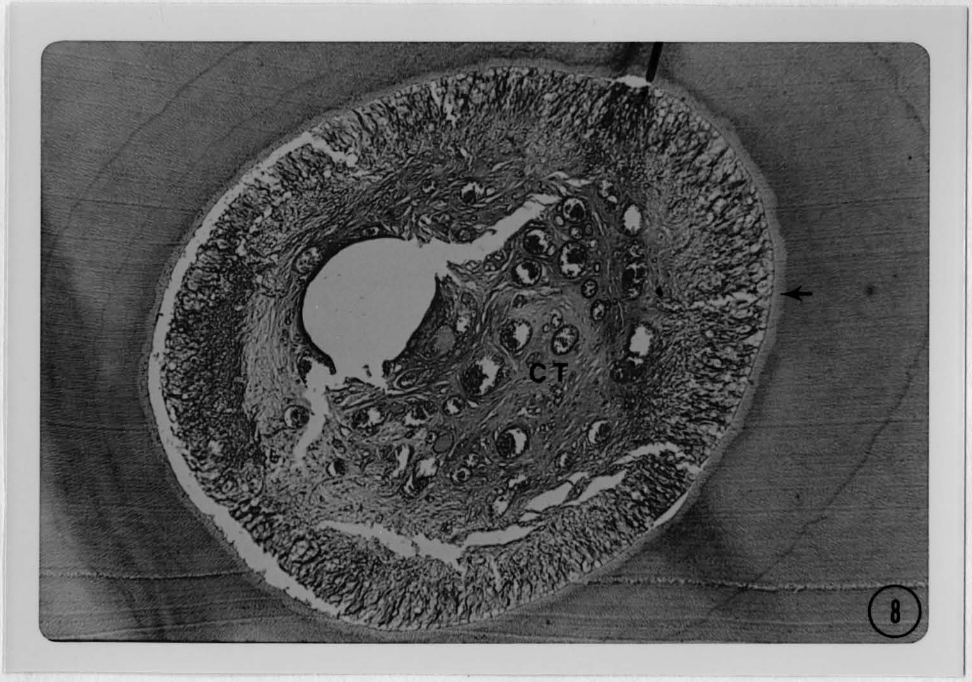
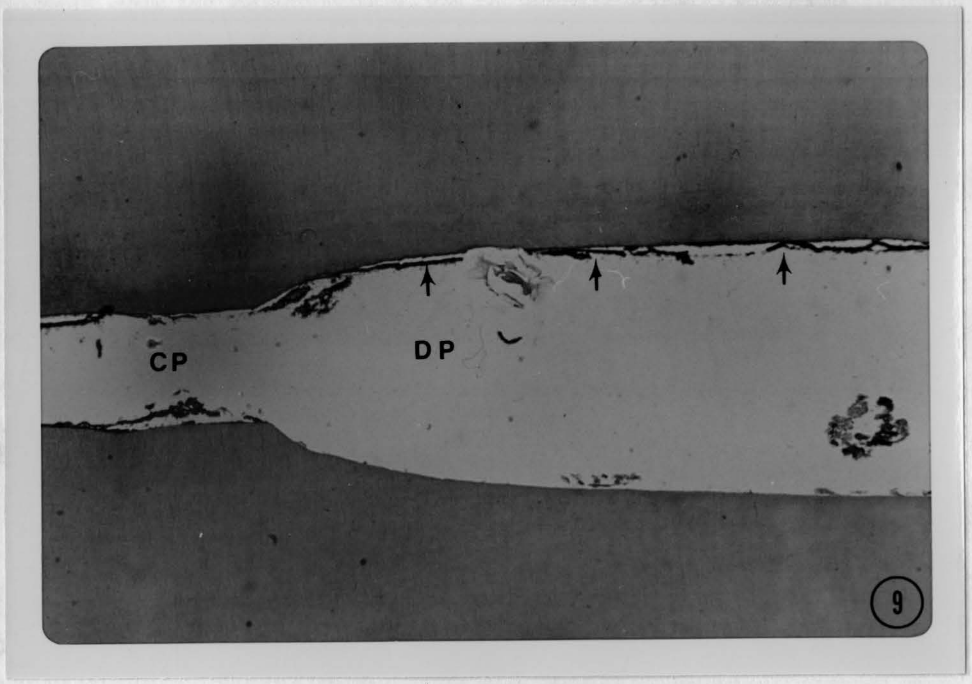

CT
8

Figure 9: Engine preparation, one day. Demarcation between dowel space preparation (DP) and canal preparation (CP). Residual sealer (arrows) is observed on one side of canal wall. (Longitudinal section, hematoxylin and eosin stain. Original magnification, X25)


CP
DP
9

APPROVAL SHEET

This thesis, submitted by Eugene C. Hanson, has been read and approved by three members of the faculty of the Department of Oral Biology.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

May 2, 1977

Date

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Signature of Advisor